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ABSTRACT

The Science Teachers as Research Scientists (STARS) program is a scientific work experience program conducted at the University of Missouri-St. Louis that provides secondary science teachers internships with faculty researchers. This report evaluates the STARS program with respect to the teachers' (n=17) first summer experiences only. Both quantitative and qualitative measures were used to evaluate the program's effectiveness and to determine whether the project objectives were met, the value of the program as perceived by the participants, and the impact of the program. The study concluded that teachers perceived that: (1) the experience in scientific research design and experimentation was substantial; (2) they made gains in their acquisition of science content knowledge; (3) they moderately increased their ability to perform science process skills; (4) they moderately increased the incorporation of research/process methodologies in their curricula; (5) they made substantial gains in their understanding of science applications in the workplace; (6) the program was helpful in lesson planning; (7) the program was valuable; and (8) the program impacted their ability to implement hands-on laboratory-oriented curricula. Field notes and classroom observations, however, do not reflect an increase in the use of these strategies in the classroom, suggesting the need for further research concerning how these changes in perception can be converted to changes in the classroom. (MDH)

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A FORMATIVE EVALUATION OF
A SCIENTIFIC WORK EXPERIENCE PROGRAM FOR SCIENCE TEACHERS

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A FORMATIVE EVALUATION OF A SCIENTIFIC WORK EXPERIENCE PROGRAM FOR SCIENCE TEACHERS

Introduction

The Science Teachers as Research Scientists (STARS) program is a scientific work experience program conducted at the University of Missouri-St. Louis (UMSL). Scientific work experience programs are those in which teachers work within businesses, industries, or universities in a variety of roles. These programs can be grouped into three categories according to the type of scientific work teachers do: project internships, research internships, and a combination of both project and research internships. In project internship programs, teachers are placed within business or industry and complete a project for the company. In research internship programs, teachers are placed in business, industry, or university settings and work with research scientists or engineers. In project/research internship programs, some teachers are placed in business, industry, or university research settings, while others are placed in business or industry with a project focus.

STARS is a research program that provides internships with faculty researchers on the UMSL campus to secondary level teachers in the St. Louis, Missouri metropolitan area. This program was developed during the 1989-90 academic year as an outgrowth of a 1988 planning session on inservice training of teachers. Participants at this meeting, which included members of the St. Louis Public School District and the University of Missouri-St. Louis faculty, identified factors important in

science teacher inservice education that could lead to improvements in student achievement. These factors include:

- a.) enhancement of the content knowledge background of teachers,
- b.) increased contact with workplace applications for science skills,
- c.) a strong understanding and practice of hands-on and process-oriented teaching techniques, and
- d.) interaction with university faculty to develop needed skills and understandings.

The STARS summer research internship/curriculum development program was developed to meet inservice needs while addressing these factors.

It is important to note that over 80 scientific work experience programs are now in existence in the United States (Industry Initiatives for Science and Math Education [IISME], 1991). Therefore, the implications of the evaluation methodologies selected and the results of the evaluation of the STARS program has the potential to impact the implementation and evaluation of programs across the United States. Currently, the primary means of evaluation of scientific work experience programs are teacher and mentor questionnaires; teacher interviews, and pre-to-post program teacher and student attitude questionnaires (Gottfried, et al, 1993).

Objectives of the STARS program

The goal of the STARS program is to provide meaningful inservice experiences in scientific research, science education theory, and curriculum development for teachers in the St. Louis metropolitan area. The specific objectives of this program are to:

- (a) provide teachers with experience in scientific research design and experimentation,
- (b) enhance teachers' understanding of the nature of science,
- (c) upgrade teachers' science content knowledge and science process skills,
- (d) increase teachers' knowledge regarding applications of science in the workplace,
- (e) upgrade teachers' skills in the implementation of learning cycle and inquiry strategies in science teaching, and
- (f) guide teachers in the preparation of laboratory-based curriculum projects based on their research experiences.

Structure of the STARS program

The STARS program has been conducted on the University of Missouri-St. Louis campus beginning with the selection of the first teacher/interns in the spring of 1990. Eight teachers were selected for the 1990 summer program; seven teachers were selected for the 1991 summer program, including two "returning"

teachers from the 1990 program; and five teachers were selected for the 1992 summer program, including one returning teacher from the 1991 program. This report evaluates the STARS program with respect to the teachers' first summer experiences only ($N=17$).

Teachers were selected for internships based on written applications and interviews that determined a "best fit" of research interests among the teachers and the researchers. Teachers worked with researchers in the departments of biology, chemistry, and physics for six weeks, five days per week during the months of June and July. Each teacher's experience was unique in that it was determined by the nature of the research being pursued by the faculty scientist with whom s/he worked. In addition, the manner and extent of the involvement of the teacher in the research was determined by the teacher's ability and background, and the ability of the researcher to train the teacher in appropriate research methodologies within the time available.

Each Friday morning the teacher/interns participated in curriculum development workshops. The first two sessions of these workshops focused on an introduction, or for some a review, of learning cycle strategy to develop laboratory materials in their classrooms. This teaching strategy was selected because it reflects the investigative nature of science.

After two sessions of introduction, review and application of the learning cycle strategy in curriculum development, teachers presented a summary of their research projects, and

worked to brainstorm ideas for curricular materials based on their research. (This was the hardest link for teachers to make, although some were quite successful.) During the next two workshops (and on their own time), the teachers developed laboratory-based curricular materials to implement in their classrooms. During the final session, the teachers presented the materials they prepared. In addition to the development of curricular materials for their classes, the teachers were also instructed in the use of scenarios in their classrooms to help students develop expertise in science process skills, such as identifying problems, developing testable hypotheses, identifying independent and dependent variables, summarizing data, and drawing conclusions from data.

After returning to school in the fall and using their curricular materials with their students, the teachers further refined them. After final revision, they were printed for dissemination to colleagues.

The Formative Evaluation

Prior to the 1990 summer program, a formative evaluation procedure was designed. Both quantitative and qualitative measures were used to evaluate the program's effectiveness and determine whether project objectives had been met. Along with determining whether project objectives had been achieved, other critical aspects of the program were also evaluated such as: the

value of the program as perceived by the teachers and the researchers, the impact of the program on the ability of the teacher to implement a hands-on laboratory-oriented curriculum, and the manner in which the program was structured. Initially, five different instruments were used:

- (a) The Test of Integrated Process Skills (TIPS), developed and validated by James Okey of the University of Georgia and F. Gerald Dillashaw of Bradley University;
- (b) The Science Classroom Activity Checklist, developed and validated by L.H. Kockendorfer of Valparaiso University;
- (c) two teacher questionnaires developed by the project director; and
- (d) one researcher questionnaire developed by the project director.

The results from the researcher questionnaire focus on management issues and are not reported here.

Prior to the beginning of the second summer, a questionnaire was designed to gather pre- and post-program data regarding the amount of class time teacher/interns spent using specific teaching strategies. These data are reported under the heading "Pre- and Post-program Teaching Strategies." In addition, a graduate student observed a class of each teacher twice prior to the program and twice six months after the program ended for the 1991 and 1992 programs. The classes visited were the same classes that were surveyed using the Science Classroom Activity Checklist. Funding and time restrictions precluded the

continuance of observations until data saturation was reached. The field notes from these observations are currently being coded and analyzed.

The Test of Integrated Process Skills (TIPS)

The TIPS test was administered to teachers during the orientation session and during the final science education workshop. The science process skills tested in this instrument are those associated with planning, conducting, and interpreting results from investigations. Usually referred to as the integrated science processes, they include formulating hypotheses, operationally defining, controlling and manipulating variables, planning investigations, and interpreting data. The test consists of 36 items.

Table 1 lists the means of the pre- and post-test scores the teachers obtained on the TIPS test. The mean gain of 1.8 points was not statistically significant. However, eight out of the 17 teachers scored above 80% on the pre-test (29 items correct), suggesting a possible "ceiling effect": these teachers could show improvement in the post-test on seven or fewer items. Therefore, the TIPS test may not be a rigorous enough evaluation tool for this group. The original search for instruments measuring process skill development was quite extensive and yielded few instruments. The one chosen was considered the most appropriate to measure process skill attainment associated with hands-on laboratory research.

The Science Classroom Activity Checklist

The Science Classroom Activity Checklist is a 53-item instrument in which a student answers true or false to a descriptor regarding behaviors of the teacher, behaviors of the students, or the nature of the use of textbooks, tests, and other materials in the classroom. If the statement describes what actually occurs in the classroom, the student response is "true." If the statement does not describe what occurs in the classroom, the student response is "false." For each statement, there is a favored response. For example, item nine reads: "My job is to copy down and memorize what the teacher tells us." The favored response to this item is "false."

There are seven categories of items in the Science Classroom Activity Checklist. The category names are listed on Table 2. The first eight questions regard the role of the teacher in the classroom. Favored responses describe the teacher as encouraging student discussion, showing students the tentative nature of science, and encouraging students to think beyond facts to the development of ideas. The favored responses of the next eight questions describe a classroom in which students are the center of activity as they probe, question, and learn. The favored responses of items 17 - 23 describe textbooks as only one source of information used in the classroom, and not as an encyclopedia of terms to be memorized. In the category "design and use of tests," favored responses indicate that test questions are used to evaluate a student's ability to apply information

learned in the laboratory, develop answers to new problems, and synthesize information from various sources, rather than solely focusing on recall. The last three categories focus on the laboratory itself. The favored responses to questions 30 - 37 describe lab activities that link to other classroom activities, discussions, or questions and are used to investigate phenomena rather than to verify statements made by the teacher or the textbook. The favored responses to questions 38 - 46 describe student-centered, teacher-involved laboratory activities that may yield varying data that need not be interpreted in only one "correct" way. The favored responses in the last category, lab follow-up activities, describe a situation in which students compare data with one another, attempt to explain unusual data, and are allowed to go beyond the regular laboratory exercise and do some experimenting on their own.

The Classroom Activity Checklist was administered to one of each teacher's "general" classes prior to the end of the school year. After the STARS program and five months into the following school year, the Checklist was administered to an equivalent class that met at a similar time of day. The pre-STARS checklist scores were each determined by totalling the number of favored responses and totalling the number of unfavored responses in each category for each teacher. The number of unfavored responses was subtracted from the favored responses to yield a score. However, these scores cannot be compared among teachers since each teacher had a different number of student

respondents, and not all categories contained the same number of items. Therefore, the scores were transformed by dividing the score by the number of items times the number of students to yield equivalent data. T tests were performed to compare the pre- and post-test scores in each category. None of the results were statistically significant.

Summer Teacher Questionnaire

A teacher questionnaire was developed to determine the teachers' perceptions regarding the increase in their understandings and knowledge in content and pedagogy. This questionnaire was administered, along with the TIPS test, on the last day of the assistantship. Figure 1 shows that the mean scores on a Likert-type scale ranging from a low of 1 to a high of 5 ranged from 3.2 to 3.9.

Teachers also had an opportunity to comment on each question they rated. Comments that appeared frequently were:

- * an expression of excitement regarding working in the laboratory, including the idea that the experience impacted their understanding of the nature of scientific research;
- * delight in the freedom to visit other labs and talk to faculty members, graduate students, and post docs; and
- * the desire to extend the experience to another summer or to Saturdays during the year.

Comments include:

"By talking with the researchers, their assistants and the graduate students, it was like being exposed to tailor-made PBS

specials on a daily basis."

"Hopefully I will be able to convey to students that research is not a 30-minute period of time spent in a lab one day a week followed by checks mailed to your home and announcement of Nobel Prizes. Research is hard work that takes a long time."

Six-Month Follow-up Teacher Questionnaire

A second teacher questionnaire was developed and administered to the STARS teachers six months after the summer experience, to evaluate the teachers' perceptions of the impact of the program on their teaching. Figure 2 shows the first portion of their responses. The mean scores on a Likert-type scale ranging from a low of 1 to a high of 5 ranged from 3.5 to 4.1. Representative selected comments teachers made were:

- * "The hands-on experiences reminded me how much can be learned by having to think through process."
- * "At my school, students spend two hours weekly in the lab. I have developed many new labs, and want to say that my students get quality hands-on laboratory, influenced by the STARS program."
- * "The people with whom I worked were inspiring. Their ideas and support gave me more confidence in the lab."
- * "I told all of my fellow teachers about the wonderful program, as well as the other departments at one whole district."
- * "The experience was positive, and I ended up sharing with everyone no matter what subject they taught. I also presented

material at the department head meeting."

- * "I am not so afraid of physical science anymore."
- * "I have incorporated new content into society and technology topics from the discipline of chemistry."
- * "I now help seniors with their science projects."
- * "The learning cycle strategy gives me more time to help students help themselves."
- * "The learning cycle strategy reminds me that what kids really master is important."
- * "I am in the process of developing a packet for the needs of my building on the research process for the department to use."
- * "I have curtailed some of my abstract teaching activities and gone more toward an investigative approach."
- * "My use of lab work has increased exponentially. I do have to rewrite most of the labs, though, to make them more in keeping with the strategies learned this past summer."

Figure 3 shows the second portion of the teacher responses from the six-month follow-up questionnaire. These items were designed to reflect the categories on the Science Classroom Activity Checklist, with the last three categories of the Checklist incorporated into one item. The mean scores on a Likert-type scale ranging from a low of 1 to a high of 5 show that teachers felt the greatest impact of the program regarded their use of lab follow-up activities. Representative selected teacher comments include:

- * "I now let the students do more discovery -- I don't just tell

them the answers. I give them an opportunity to find out for themselves."

- * "It reminded me to think process and understanding and not to be a slave to the curriculum guide (teach dry facts only)."
- * "The lab is a big change. My students are in the lab 25% of the class time, which amounts to 2 days/week every two to three weeks. (Some of the students have never done lab work before!)"

When asked to make suggestions to improve the program, the teachers indicated a desire to spend two mornings per week in the curriculum development workshop. In addition, they expressed a desire to return the following summer to continue their research projects.

Pre- and Post-program Teaching Strategies

In answering post-program questionnaires after the 1990 program, teachers reported that they perceived a change in the amount and kind of teaching strategies toward a greater use of hands-on laboratory-oriented strategies as a result of participating in the STARS program. To gather further data, the teachers in the 1991 and 1992 programs ($N=8$) responded to a questionnaire prior to the start of the summer program and six months after the program end. Teachers were given a list of the following teaching strategies and told to report the percent of class time they spent using each: lecture, laboratory activities, non-laboratory hands-on activities, discussion, demonstrations, student presentations, reading from the textbook, students

answering questions orally, students answering questions from the textbook or on worksheets, and other (name or describe).

To analyze these data, the Sign Test was used. The Sign Test is a non-parametric paired-sample test. To analyze the data, first two categories of activities were developed from the above list: (1) laboratory and/or hands-on activities and (2) non-laboratory and/or non-hands-on activities. The teaching strategies from the teacher list that were considered as part of group (1) are laboratory activities, non-laboratory hands-on activities, and demonstrations. The other strategies were not considered a part of this group. Table 3 shows the percent of group (1) activities teachers reported using before the STARS program and the percent of group (1) activities after the STARS program. A positive or negative difference pre-post is noted. The Sign Test shows no significant difference in the amount of group (1) activities before and after the STARS program.

Summary and Conclusions

- 1.) Teachers perceive that they received a somewhat substantial amount of experience in scientific research design and experimentation.
- 2.) Teachers perceive that they made somewhat substantial gains in their acquisition of science content knowledge. In addition, teachers perceive that they have incorporated this content into their curricula in a somewhat substantial way.

3.) Teachers perceive that they moderately increased their ability to perform science process skills. Pre- and post-testing of science process skill attainment shows no significant gains in teachers' ability to perform science process skills after participation in the STARS program. Possibly, the skills acquired by teachers in their internships may be narrow and specific to each internship, therefore difficult to measure with a "generic" instrument.

4.) Teachers perceive that they have somewhat substantially increased the incorporation of research/process methodologies into their curricula. In addition, teachers perceive that their teaching strategies have changed somewhat substantially as a result of their summer experiences.

5.) Teachers perceive that they have made somewhat substantial gains in their understanding and knowledge of applications of science in the workplace.

6.) Teachers perceive that the learning cycle and inquiry strategies learned during the program have been helpful in their day-to-day lesson planning. In addition, teachers perceive that they have made somewhat substantial gains in their ability to design activities for classroom use.

7.) Permeating many comments of the teachers on questionnaires was the high degree to which they valued the program. The teachers are sharing their experiences and perceptions of the program with fellow teachers and administrators.

8.) The teachers perceive that the program has substantially

impacted their ability to implement hands-on laboratory-oriented curricula. However, the Science Classroom Activity Checklist and the pre-to-post program questionnaire on teaching strategies do not reflect an increase in the use of these strategies in the classroom. These data suggest that either (a) the methods we are using are not detecting changes that exist, or (b) that observable, measurable change is not taking place. Analysis of the field notes of classroom observations may yield data that contribute to the resolution of this dichotomy.

The data from teacher interviews and questionnaires suggest that some type of change is occurring in teacher practice. This change may involve the way in which a teacher views what she or he does; after the internship experience teachers appear to view their roles in their classrooms through different "lenses," which impacts their decision making in ways we have yet to measure. Researching changes in teacher decision making may be an interesting and fruitful area of research regarding teacher change as a result of participating in a research internship.

Our future research projects will focus on gaining understanding regarding changes that occur in teachers' knowledge, skills, and attitudes; how these changes translate into changes in classroom practice, teacher professionalism, and teachers' abilities to act as change agents; and the components or facets of scientific work experience programs that foster those changes. This information will be important to the continuing growth of the scientific work experience program as a

model of science teacher development in ways that will best
promote excellence in science teaching across the United States.

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Table 1

MEANS OF PRE- AND POST-TEST SCORES OBTAINED ON THE
TEST OF INTEGRATED PROCESS SKILLS (TIPS)

n=17

<u>Pre-test Mean</u>	<u>Post-test Mean</u>	<u>t</u>	<u>p>.05</u>
28	29.8	0.044	ns
			CV=1.753

TABLE 2

STARS SCIENCE CLASSROOM ACTIVITY CHECKLIST (YEAR 1,2 & 3)

SUMMARY TABLE OF AMOUNT AND DIRECTION OF CHANGE BETWEEN PRE-DATA AND POST-DATA
USING TRANSFORMED SCORES

n=16

	----PRE-TEST----		----POST-TEST----		GAIN OR LOSS	T	P > .05
	MEAN	STD. DEV.	MEAN	STD. DEV.			
ROLE/BEHAVIOR OF TEACHER	18.48	13.53	17.38	13.16	-1.10	0.23	ns
ROLE/BEHAVIOR OF STUDENT	0.58	19.40	-1.59	7.82	-2.17	0.41	ns
USE OF TEXTBOOK AND REF. MATERIAL	-4.46	25.45	-2.81	17.53	1.65	0.21	ns
DESIGN AND USE OF TESTS	12.44	30.09	10.57	19.00	-1.87	0.21	ns
ROLE OF LAB AS PART OF COURSE	2.83	17.34	-1.77	12.55	-4.60	0.85	ns
TYPE OF LAB ACTIVITIES	10.28	22.94	6.66	12.93	-3.62	0.55	ns
LAB FOLLOW-UP ACTIVITIES	13.64	37.64	13.33	24.67	-0.31	0.02	ns

CV=2.042

Table 3
PRE TO POST PROGRAM QUESTIONNAIRE RESULTS REGARDING
LABORATORY AND/OR HANDS-ON TEACHING STRATEGIES

% class time spent on
lab/hands-on activities

<u>Teacher</u>	<u>Pre-program Time</u>	<u>Post-program Time</u>	<u>Difference</u>
T1	5%	25%	+
T2	20%	30%	+
T3	30%	40%	+
T4	34%	30%	-
T5	35%	60%	+
T6	70%	65%	-
T7	15%	25%	+
T8	46%	51%	+

Ho= there is no significant difference between the amount of time spent on lab/hands-on activities before participation in the STARS program and after participation in the STARS program.

n=8 6 positive differences
 2 negative differences
 $P(X \leq 2 \text{ or } X \geq 6) = 0.28908$
 Since the probability is greater than 0.05, do not reject Ho.

Figure 1

Post-STARS Teacher Questionnaire

1990, 1991, and 1992 Programs

Administered August

Approximate means of Likert Scale Items

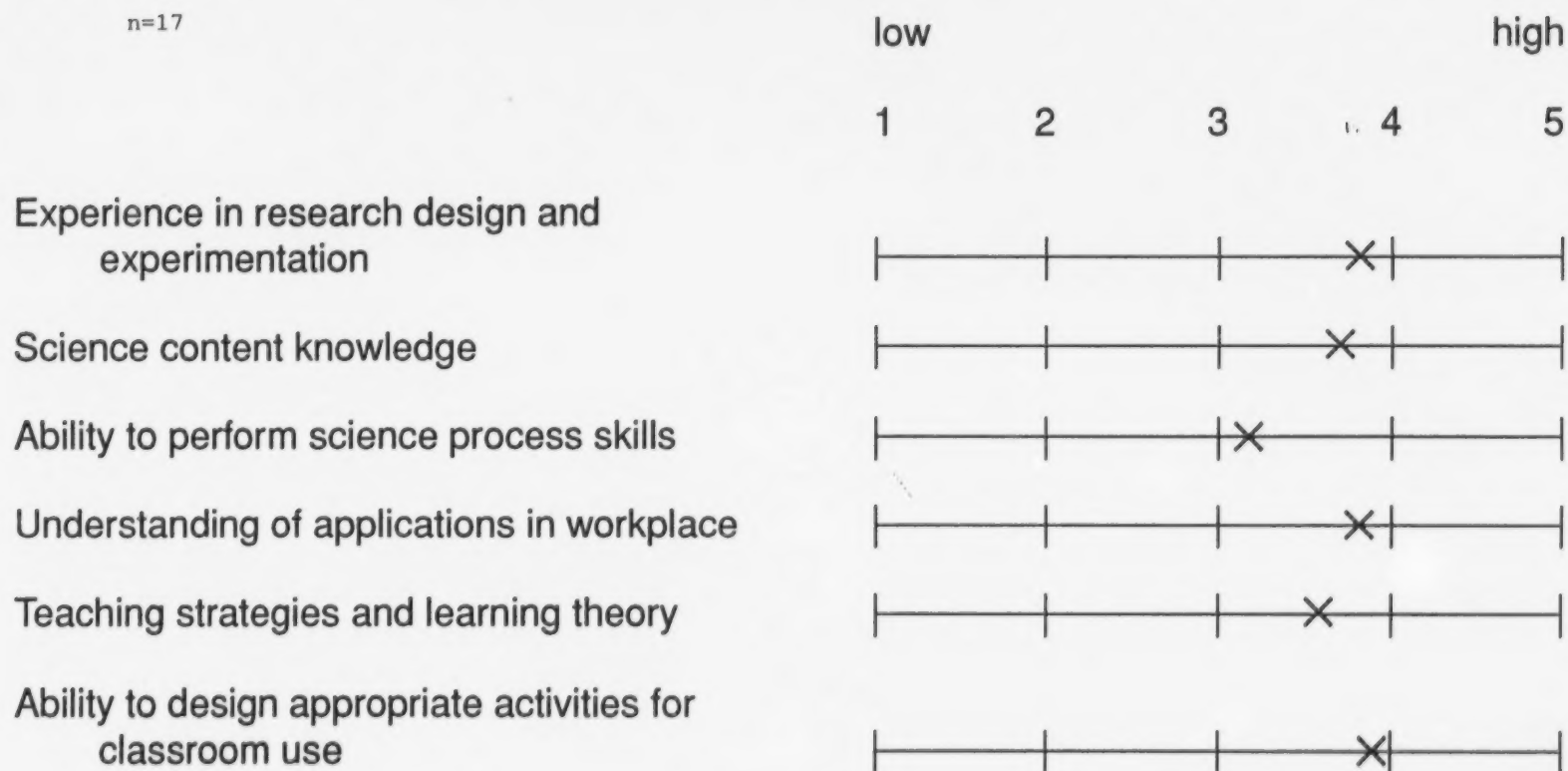


Figure 2

Post-STARS Teacher Questionnaire

1990, 1991, and 1992 Programs

Administered January

Approximate means of Likert Scale Items

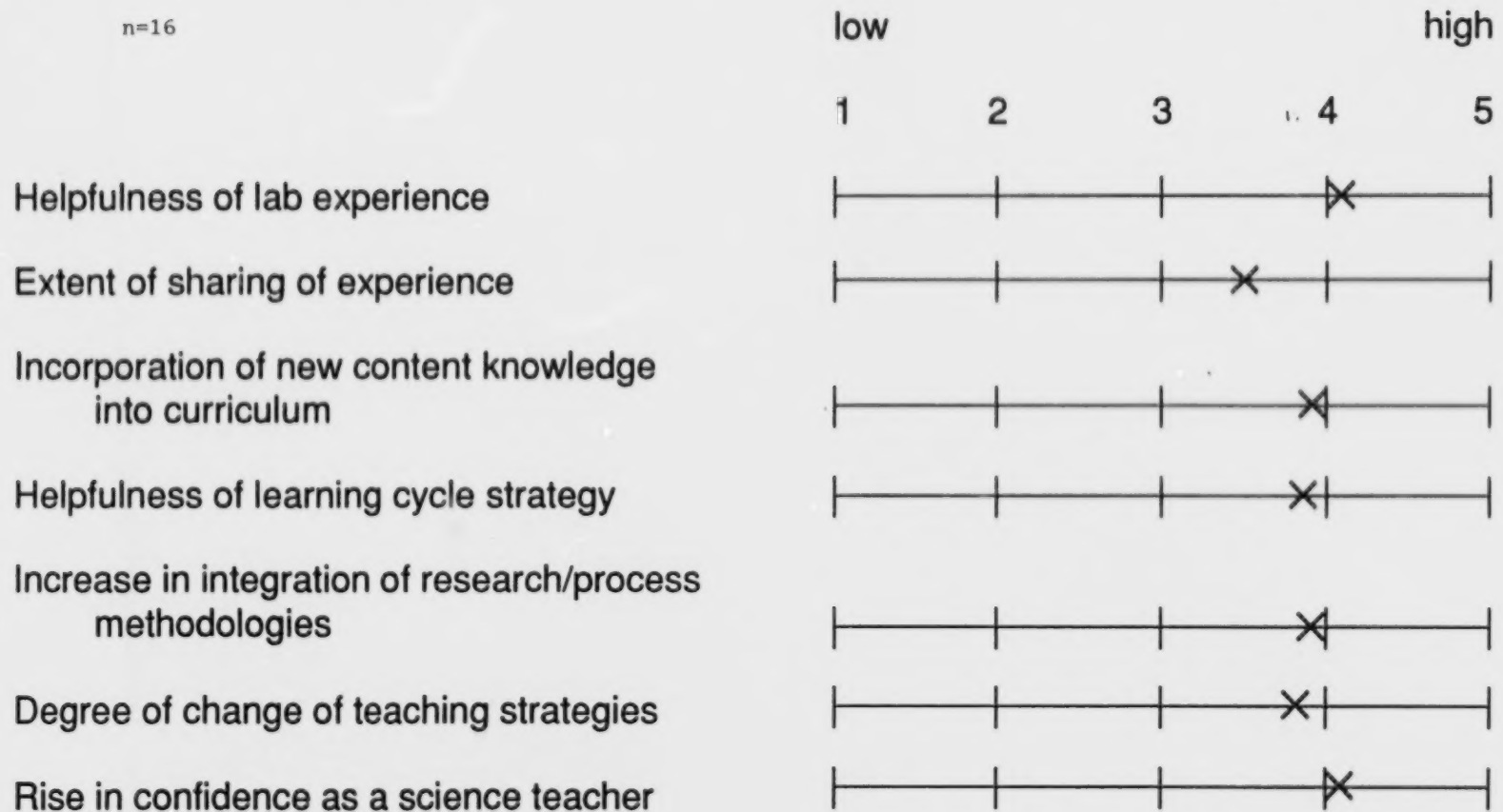


Figure 3

Post-STARS Teacher Questionnaire

1990, 1991, and 1992 Programs

Administered January

Approximate means of Likert Scale Items

n=16

low

high

1

2

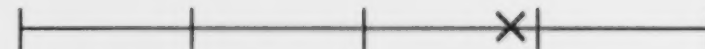
3

4

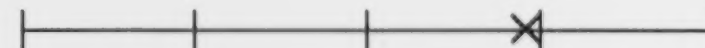
5

To what degree did the STARS program impact:

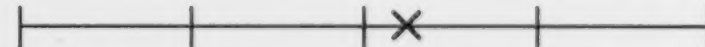
your role in the classroom



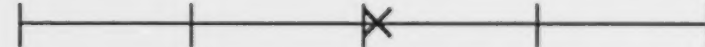
student classroom participation



use of textbooks and reference manuals



design and use of tests



lab follow-up activities

